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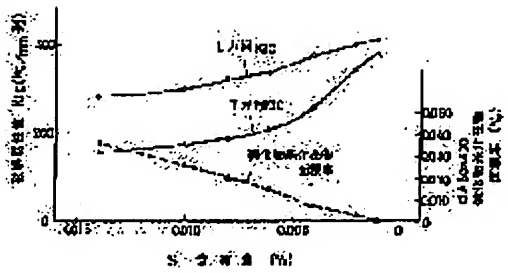
(54) TOOL STEEL FOR HOT WORKING

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a tool steel for hot working high in the levels of toughness and ductility and having isotropy small in the difference between characteristics in the T direction and the L direction.

SOLUTION: This steel has the compsn. contg., by weight, 0.10 to 0.70% C, 0.10 to 2.00% Si, ≤2.00% Mn, ≤7.00% Cr, W and Mo alone or in combination by (1/2W+Mo): 0.20 to 12.00% and ≤3.00% V, in which the content of S is regulated to <0.005% and that of O to <30 ppm, and the balance substantial Fe, and has the cleanliness so that nonmetallic inclusions present in the steel is regulated to JIS dA60×400≤0.010% and d(B+C) 60×400≤0.020%. Moreover, the steel may contain one or more kinds among ≤4.00% Ni, ≤6.50% Co and ≤0.20% N and is preferably subjected to soaking treatment.



CLAIMS

[Claim(s)]
[Claim 1] By the weight ratio, C:0.10 - 0.70%, Si:0.10-2.00%, By independent or compound of Mn<=2.00%, Cr<=7.00%, and W and Mo : (1/2 W+Mo) 0.20 - 12.00%, V<=3.00%, less than further S:0.005%, and O are less than 30 ppm. The cleanliness of the nonmetallic inclusion which has the presentation which the remainder becomes from Fe substantially, and exists in steel is JIS. Tool steel for hot working characterized by being d (B+C) 60x400<=0.020% 60x400<=0.010% of dA(s).
[Claim 2] By the weight ratio, C:0.10 - 0.70%, Si:0.10-2.00%, By independent or compound of Mn<=2.00%, Cr<=7.00%, and W and Mo : (1/2 W+Mo) 0.20 - 12.00%, V<=3.00% is contained. Further nickel<=4.00%, Co<=6.50%, Less than further S:0.005% and O are less than 30 ppm N<=0.20% of more than a kind. The cleanliness of the nonmetallic inclusion which has the presentation which the remainder becomes from Fe substantially, and exists in steel is JIS. Tool steel for hot working characterized by being d (B+C) 60x400<=0.020% 60x400<=0.010% of dA(s).
[Claim 3] Claim 1 characterized by coming to give soaking processing thru/or tool steel for hot working given in 2.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] Since this invention is used for various metal mold applications between heat, such as a mold for hot forging, an aluminum die-casting mold, and an aluminum extrusion dice, a crack is not produced to an operation of severe thermal and mechanical stress, a longevity life can be obtained and it is hard to produce a crack, It can be used being able to raise hardness and the toughness which makes it possible to acquire the antifriction life which was excellent as this result, and ductile level are related with the tool steel steel materials for hot working highly equipped with isotropy with little directivity.
[0002]
[Description of the Prior Art] The problem of the early large crack of a mold was raised, and the advancement of forging precision became poor [a product dimension and a configuration] in slight sagging of a mold face, and the phase of wear, and the example to which metal mold reaches a life at an early stage has increased the Sharp corner-ization of the mold for raising severe-izing of cooling from the mold face for gathering configuration complication of a mold in recent years, enlargement, and shaping effectiveness, and forging precision. In this case, although raising hardness was examined in order to prevent early setting and wear, it is loam ****** about the early large crack.
[0003] In the case of the conventional tool steel steel materials for hot working, the fiber at the time of hot working of a material is met. A crack occurs or Progress, The toughness value in the case of destroying, i.e., the toughness value of the direction of cogging and the direction of a right angle, (the direction toughness value of T) Are low to a toughness value (the direction toughness value of L), i.e., the toughness value of the direction of cogging, in case a crack progresses and breaks in the direction of a right angle to a fiber. (For example, the direction toughness value of T / direction toughness value of L = 0.6 etc.) Therefore, destruction tended to advance along the direction of a fiber, and it was a problem of the utmost importance for the improvement in a life of the toughness of the direction of T of a material and a ductility improvement.
[0004]
[Problem(s) to be Solved by the Invention] In the case of the conventional steel materials, to the toughness value (the direction toughness value of L) of a direction parallel to the direction of cogging, above for example, 60% in the case of a parallel sample and the clearly low things of ** by the sample of the direction of a right angle and ductile (the direction toughness value of T) level are usually, and the crack-proof life of metal mold was influenced by this **, ** of the ductile low direction of a right angle, and ductile level in many cases. It is easy to produce the letter destruction of exfoliation into the parts of the nonmetallic inclusion extended for a long time in the direction of cogging as a cause of that difference, or the dense inclusion, and, for this reason, meets in the direction of a fiber, and a crack occurs and becomes easy to progress, Moreover, the component segregation concentration of the stripes-like segregation extended in the direction of cogging was high, and **** was wide, and when having arranged with directivity strong against the direction of a fiber, it was the main factor to which a crack tends to progress to linearly along with a stripes-like segregation, and this is reducing the toughness of the direction of a right angle.
[0005]
[Means for Solving the Problem] Especially in this invention, mileage, and the amount and magnitude of cone sulfide system inclusion are reduced to a limit in the direction of cogging. Moreover, the pole clarification steel which reduced a silicate system and oxide system inclusion to pole small quantity is obtained efficiently. By combining reduction of the microsegregation by the still more suitable diffusion soaking, control of the configuration of the nonmetallic inclusion by hot working which carried out suitable management of a **** multiplier, etc. Reduce the inclination of destruction by the gestalt mentioned above, and both the toughness level of the direction of cogging and the direction of a right angle is raised. And it is what is going to raise the toughness value of the direction of a right angle to the

level (isotropy) equivalent to parallel it which is, carries out and applies to this. moreover -- the dissolution and the ingot making approach -- a cost rise and efficiency fall of vacuum remelting, consumable electrode type remelting, etc. -- imitating -- ** -- it is not based on a special approach but solves in mass-production methods, such as refinement an electric furnace refinement-furnace outside.
[0006] The 1st invention of this invention by the weight ratio Namely, C:0.10 - 0.70%, Si:0.10-2.00%, By independent or compound of Mn<=2.00%, Cr<=7.00%, and W and Mo : (1/2 W+Mo) 0.20 - 12.00%, V<=3.00%, less than further S:0.005%, and O are less than 30 ppm. The cleanliness of the nonmetallic inclusion which has the presentation which the remainder becomes from Fe substantially, and exists in steel is JIS. It is the tool steel for hot working characterized by being d (B+C) 60x400<=0.020% 60x400<=0.010% of dA(s). As for the steel of the 1st invention of the above, it is good that it is the isotropy to which the direction toughness value of T / direction toughness value of L which is the ratio of the toughness value (the direction toughness value of L) and the toughness value of the direction of a right angle of the direction of cogging (the direction toughness value of T) exceed 0.70. Moreover, for S, the cleanliness of less than 0.003% and nonmetallic inclusion is [the range of the steel of the 1st invention of the above] JIS. It is good for 60x400<=0.005% of dA(s), and the direction toughness value of T / direction toughness value of L to consider as 0.85 or more isotropy.
[0007] Furthermore, the 2nd invention by the weight ratio C:0.10 - 0.70%, Si:0.10-2.00%, By independent or compound of Mn<=2.00%, Cr<=7.00%, and W and Mo : (1/2 W+Mo) 0.20 - 12.00%, V<=3.00% is contained. Further nickel<=4.00%, Co<=6.50%, Less than further S:0.005% and O are less than 30 ppm N<=0.20% of more than a kind. The cleanliness of the nonmetallic inclusion which has the presentation which the remainder becomes from Fe substantially, and exists in steel is JIS. It is the tool steel for hot working characterized by being d (B+C) 60x400<=0.020% 60x400<=0.010% of dA(s). As for the steel of the 2nd invention of the above, it is good that it is the isotropy to which the direction toughness value of T / direction toughness value of L which is the ratio of the toughness value (the direction toughness value of L) and the toughness value of the direction of a right angle of the direction of cogging (the direction toughness value of T) exceed 0.70. Moreover, for S, the cleanliness of less than 0.003% and nonmetallic inclusion is [the range of the 2nd invention of the above] JIS. It is good for 60x400<=0.005% of dA(s), and the direction toughness value of T / direction toughness value of L to consider as 0.85 or more isotropy.
[0008] the precipitation-strengthening grant elements Cu, B, aluminum, and Be according the special carbide formation elements Nb and Ti etc. to 0.50% or less and intermetallic-compound formation by independent or compound to the presentation of the steel of the 1st invention of the above, and the steel of the 2nd invention etc. -- independent or compound -- various alloying elements, such as 3.00 etc.% or less, -- content **** -- things are made.
[0009]
[Embodiment of the Invention] The role of various elements required as tool steel for hot working of this invention is described below. At the time of hardening heating, it dissolves on a base and required hardening hardness is given, and at the time of tempering, special carbide is formed between special carbide formation elements, it deposits, and the softening resistance and high temperature strength in tempering are given, and a lipobiolite ghost is formed, the abrasion resistance in an elevated temperature is given, it has the operation which prevents big and rough-ization of the crystal grain at the time of hardening heating, and C is an important indispensable element. If many [too], the amount of carbide will increase too much, the required toughness as a tool between heat cannot be held, and the fall of high temperature strength is also imitated, it considers as 0.70% or less by that of **, and since the effectiveness of the above-mentioned addition will not be acquired if too low, it may be 0.10% or more.
[0010] An addition is adjusted by the purpose and the application for Si needing the use as a deoxidation-on manufacture element generally, raising oxidation resistance and tempering softening resistance at 500-600 degrees C or less according to an application, and getting the A1 transformation point. Since a toughness fall will be imitated, and it will come and pyroductivity will be reduced too much if many [too], it may be 0.10 - 2.00%. The effectiveness of Mn which dissolves on a base and raises hardenability is large. Mn adjusts an addition by the purpose and the application, in order to

acquire the above-mentioned addition effectiveness. Since will anneal, hardness will be made high too much, and machinability will be reduced and the A1 transformation point will be made low too much if many [too], it may be 2.00% or less.

[0011] Cr is the most important element for giving the hardenability needed as a tool. Moreover, the rise of oxidation resistance or the A1 transformation point and a lipobiolite ghost are formed, and big and rough-ization of the crystal grain at the time of hardening heating is controlled, and abrasion resistance is raised, special carbide is deposited at the time of tempering, and the softening resistance at the time of a temperature up is improved, and it is added in order to give effectiveness, such as raising high temperature strength. Since Cr carbide will be formed too much and the fall of high temperature strength will be brought about on the contrary if many [too], it may be 7.00% or less. In addition, although there may be additive-free, in order to acquire the effectiveness of the above-mentioned addition, it is good to make it contain 0.70% or more generally.

[0012] W and Mo are the most important alloying elements for forming special carbide, and preventing organization big and rough-ization at the time of hardening heating by lipobiolite ghost formation, and depositing detailed special carbide at the time of tempering, and raising tempering softening resistance and high temperature strength. Moreover, it has the effectiveness which raises the A1 transformation point. Especially W has the large effectiveness which raises high temperature strength and abrasion resistance, and, on the other hand, Mo is more advantageous than the case of W in respect of toughness. If many [too], it will consider as 12.00% or less by that of ** by independent or compound (1/2 W+Mo) of W and Mo by forming big and rough carbide and imitating too much fall of toughness, and since the effectiveness of the above-mentioned addition runs short if too low, it may be 0.20% or more.

[0013] V is a powerful carbide formation element, a lipobiolite ghost is formed and the effectiveness of grain refining gives the wear-resistant improvement in an elevated temperature greatly. Moreover, at the time of tempering, detailed carbide is deposited in radical underground, and the effectiveness which raises the reinforcement in a pyrosphere 600-650 degrees C or more by joint addition with W and Mo is large, and gives the effectiveness which raises the A1 transformation point. Although it is added in order to acquire the above-mentioned effectiveness, if there is too much V, it will form big and rough carbide, it imitates the fall of toughness, and may be 3.00% or less by that of **. In addition, although there may be additive-free, in order to acquire the effectiveness of the above-mentioned addition, it is good to make it contain 0.05% or more generally.

[0014] nickel is added by the purpose and the application, in order to dissolve on a base, and to raise toughness and to raise hardenability. If many [too], it will anneal and hardness will be made high too much, machinability is reduced, and too much fall of the A1 transformation point is imitated, and it may be 4.00% or less by that of **. Co has the operation which dissolves on a base and raises high temperature strength. Moreover, raise the solid-solution limit of the carbide to the inside of the austenite at the time of hardening heating, and the amount of deposits of the special carbide at the time of tempering is made to increase, and condensation resistance of the deposit carbide at the time of a temperature up is raised, and the effectiveness of improving a high-temperature-strength property also from this field is given. Moreover, the oxide skin of precise adhesion is made to form in a front face according to the temperature up at the time of use of a tool, and the effectiveness which raises the abrasion resistance in an elevated temperature and an antiseizure property is given. Although added by the purpose and the application for the above-mentioned purpose, since too much Co will reduce toughness if there is, it may be 6.50% or less.

[0015] N makes possible the combination of the alloy presentation which prevented the ferrite survival at the time of hardening heating also in low C, and was excellent in toughness as an austenite former in order to dissolve in a base or carbide, to make crystal grain detailed and to raise toughness. In order to acquire the above-mentioned effectiveness, it is added by the purpose and the application, but since the critical mass which can be added within the limits of the alloy presentation of tool steel between heat, such as Cr, exists, N may be 0.20% or less.

[0016] Nb and Ti are powerful carbide formation elements, and have the effectiveness which raises the softening resistance and high temperature strength in a pyrosphere 650 degrees C or more by the deposit

of especially large detailed carbide of the condensation resistance at the time of detailed-izing and tempering of crystal grain. It is added by the purpose and the application in order to acquire the above-mentioned effectiveness. If many [too], the big and rough carbide which cannot dissolve easily will be formed, the fall of toughness will be imitated, and it may be 0.5% or less by compound or independent addition by that of **. Cu, B, aluminum, and Be form an intermetallic compound, bring about the deposit effectiveness, and bring about the effectiveness of improving the softening resistance at the time of a temperature up, and high temperature strength. Since toughness will be reduced if many [too], it may be 3.00% or less by independent or compound.

[0017]

[Example] The presentation of steel and the cleanliness of nonmetallic inclusion are shown in Table 1 this invention steel of a 61 about SKD presentation of JIS, comparison steel, and conventionally. the amount [in / to drawing 1 / the stereo mold steel of SKD61 presentation] of S, and JIS -- the example of an experiment about relation with the plane strain fracture toughness value KIC of the nonmetallic inclusion cleanliness by law, the direction of cogging (the direction of L), and its direction of a right angle (the direction of T) is shown. The forging ratio in this case is 15 (a **** multiplier is 6.5). Although the amount of sulfide system inclusion and magnitude are dwindled and KIC is increased gradually with it to reduction from the amount 0.014 of S to 0.006%, especially as for the KIC value of the direction of T, the amount of S increases [the amount of S] rapidly at less than 0.003% bordering on less than 0.005%, and it is admitted that the difference by L and the direction of T decreases rapidly.

[0018] Although pointed out from the former, going in the direction which the toughness value by the direction TP of T increases by reduction of the amount of S, and approaches it of the direction of L There is a special point that the effectiveness increases [the amount of S] rapidly remarkably near less than 0.005%, especially 0.003% in the tool steel for hot working, as a result of a detailed research investigation of this invention persons. The outstanding property in which it is newly found out that the toughness value of the direction of T increases rapidly in the amount of S not more than this, and it exceeds anticipation far as various metal mold between heat is acquired.

[0019]

[Table 1]

	C	Si	Mn	S	Cr	Mo	V	O PPm	dA60×400 (%)	d(B+C)60×400 (%)
本発明鋼 A	0.39	0.87	0.41	0.001	5.21	1.38	0.70	10	0	0.008
〃 B	0.40	0.86	0.41	0.002	5.25	1.39	0.68	11	0.004	0.012
〃 C	0.39	0.85	0.40	0.004	5.24	1.37	0.70	15	0.008	0.016
比較鋼 ①	0.40	0.89	0.43	0.006	5.25	1.36	0.69	32	0.016	0.024
〃 ②	0.38	0.89	0.44	0.008	5.30	1.35	0.68	35	0.020	0.028
〃 ③	0.39	0.90	0.43	0.010	5.31	1.38	0.71	40	0.028	0.032
従来鋼 ④	0.41	0.88	0.40	0.014	5.25	1.36	0.72	37	0.036	0.032

[0020] The **** multipliers 0-L, and 20 and the relation of the KIC value of the direction of T are shown in drawing 2 about S:0.002% of this invention steel in the 61 about SKD steel materials of the heat treatment (hardening, tempering) hardness HRC45, and S:0.014% of the conventional steel. In this case, before moving to cogging, ****** is put in, and the total forging ratio has become 0-50. Although, as for S:0.014% of the conventional steel, the increment in the toughness value of the direction sample of T is seen by two or more **** multipliers and a toughness value serves as max in the four to **** multiplier 6 neighborhood in this result, it becomes only the value of about 60 percent (the ratio of the

direction toughness value of T / direction toughness value of L is about 0.6) of the KIC value in the case of the direction of L, but 10 or more order of **** multipliers shows the inclination of reduction.
[0021] On the other hand, the toughness value of the direction sample of T of the thing of S:0.002% of this invention steel increases in the **** multiplier 2 neighborhood more greatly than the case of the conventional material. Taking ** size in the four to 10 neighborhood, not to mention the direction of T of S:0.014% of the conventional steel, the value is clearly higher than the direction of L, and shows the KIC value of 90 percent or more (the ratio of the direction toughness value of T / direction toughness value of L is 0.85 or more) of the KIC value of the direction of L of this invention steel. And even if reduction of the KIC value of the direction sample of T accompanying the increment in a **** multiplier compares with the conventional material, it is hard to be generated, and the fall of the KIC value of the direction TP of T is small also before and behind the **** multiplier 20. That is, as a forging ratio, it is four (however, **** multipliers 4-10) or more desirably 1.5 (however, **** multipliers 1-20) or more.
[0022] The improvement effectiveness of the Charpy impact value of the direction of T after the forging finish at the time of taking lessons from this invention steel materials of S:0.002% of SKD61 presentation with the heat treatment (hardening, tempering) hardness HRC45, and giving slab soaking processing to drawing 3 in the **** multiplier 5.0, the steel-ingot soaking in the case of a forging ratio 12.0, and the phase of a forging ratio 2.3 (**** multiplier 1) is shown. The soaking temperature in this case is 1200 degrees C or more. By reducing the microsegregation at the time of coagulation by soaking processing, when the ratio of the direction Charpy impact value of T / direction Charpy impact value of L had no soaking, it was admitted to being 0.88 that Charpy impact value of that to which what performed the steel-ingot soaking performed 0.90 and a slab soaking was improving by performing a soaking by 0.92.
[0023] In order to obtain this invention steel, after advancing to oxidizing-refining -> reduction refinement beforehand and setting the amount of [O] in molten steel to 100 ppm or less in an electric furnace, it is effective to advance desulfurization and deoxidation efficiently by refinement furnace outside. Under the present circumstances, it is more effective to make coincidence reduce the amount of [O] in molten steel further to less than 30 ppm by Ar blowing in from a lower part in to advance desulfurization for a short period of time by refinement furnace outside of an electromagnetic-mixing method to less than S:0.005% of super-low level and this case, in order to advance desulfurization by the slag-molten steel reaction efficiently, and to accelerate the desulfurization effectiveness further etc. As shown in the above-mentioned table 1, S is [less than 0.005% and O] less than 30 ppm, desirably, S is less than 0.003%, O is less than 30 ppm, and there is very little this invention steel as compared with steel conventionally. Moreover, as cleanliness of the nonmetallic inclusion which exists in steel, it is JIS. It is d (B+C) 60x400<=0.020%, and the amount and magnitude of sulfide system inclusion or oxide system inclusion are desirably reduced extremely 60x400<=0.010% of dA(s) as compared with steel conventionally at 60x400<=0.005% of dA(s).
[0024] The heat treatment (hardening, tempering) hardness HRC44 shows the impact transition property by the direction test piece of T of this invention steel materials of S:0.002% of SKD61 presentation, and the conventional steel materials of S:0.014% of SKD61 presentation to drawing 4 . A test piece is JIS. It examined at 20-300 degrees C by the piece of a V notch Charpy test, and change of the absorbed energy of fracture was investigated. The forging ratio of a material is 12.5 and a **** multiplier is 5.0. In the case of S:0.014% of the conventional steel materials, 50%, brittle-fracture-appearance transition temperature is 50-100 degrees C, the increment in the absorbed energy to a test temperature is seen, but the degree of the increment is small in the temperature region exceeding 100 degrees C. On the other hand, in the case of this invention steel materials, 50% brittle-fracture-appearance transition temperature is 50-100 degrees C similarly, but whenever [increment / in the absorbed energy to the rise of a test temperature] is clearly large. For this reason, in the case of the metal mold using this invention steel materials, impact absorbed energy by the mold preheating can be enlarged, to the case where the crack reduction effectiveness is steel materials conventionally, it is conspicuous and a large thing is accepted.
[0025] To Table 2 SKT4 of 0.52%C-0.21%Si-0.85%Mn-1.65%nickel-1.03%Cr-0.40%Mo-0.16%V-

balFe, SKD8 of V-4.30% Co-balFe of W-0.35% Mo-1.98% of 0.40%C-0.22%Si-0.34%Mn-4.36%Cr-4.35%, The 3nickel-3Mo system of 0.19%C-0.25%Si-0.60%Mn-3.32%nickel-3.42%Mo-balFe, About the tool steel between [several sorts of] heat of 10 Cr-Mo-V-N system of 0.31%C-0.33%Si-0.65%Mn-10.25%Cr-1.58%Mo-0.97%V-balFe The ratio of the direction toughness value of T and the direction toughness value of L is shown in the plane strain fracture toughness value list of the direction of L of steel materials, and the direction of T this invention steel materials and conventionally. It turns out that it has 0.85 or more [to which the toughness of the direction of T is conventionally low in the case of steel materials, and the toughness of the direction of T of this invention steel materials is conspicuous, and it excels to the ratio of the direction toughness value of T / direction toughness value of L being less than 0.70, and the ratio of the direction toughness value of T / direction toughness value of L exceeds 0.70 far] outstanding isotropy.

[0026]

[Table 2]

試料		平面歪み破壊靭性値 (kg/mm$^{3/2}$)		T方向靭性値／L方向靭性値
		L	T	
SKT4 (HRC41)	従来材 0.013%S	335	224	0.67
	本発明材 0.002%S	350	322	0.92
SKD8 (HRC44)	従来材 0.012%S	135	88	0.65
	本発明材 0.001%S	140	125	0.89
3Ni-3Mo (HRC38)	従来材 0.013%S	262	173	0.66
	本発明材 0.002%S	270	245	0.90
10Cr-Mo-V-N	従来材 0.011%S	320	218	0.68
	本発明材 0.001%S	330	304	0.92

[0027] Moreover, the example of a comparison of the die service life at the time of using this invention steel materials and the conventional material for a hot press forge mold is shown in Table 3.

[0028]

[Table 3]

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[0029] Since generating of a crack stopped being able to progress easily by having been late due to application of this invention steel materials and a large crack did not arise, the die service life improved the twice of the conventional material, and it became clear that stabilization is achieved and practicality ability is improved sharply. Moreover, also in the aluminum die-casting die using this invention steel materials of SKD61 presentation, and the hammer metal mold between heat using this invention steel

materials of SKT4 presentation, the 2 to 3 times [at the time of using the conventional material] as many longevity life as this is obtained.

[0030]

[Effect of the Invention] Since the difference of the property of the direction of T and the direction of L is equipped highly [toughness and ductile level] with little isotropy by the tool steel for hot working of this invention as shown above, in the applied various metal mold between heat, an early large crack is not produced, but generating of a crack is slow, and since it is hard to progress, stabilization can be attained along [long lasting] a mold.

[Translation done.]

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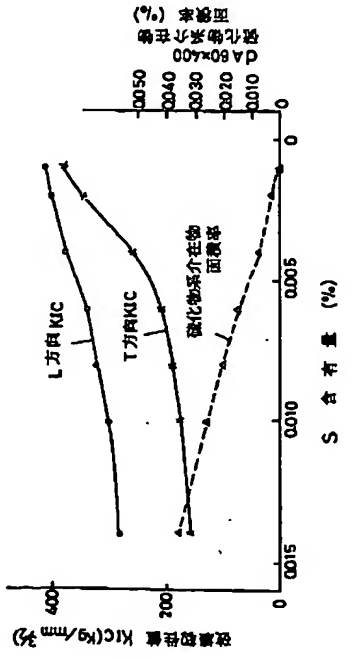
最終頁に続く

(54)【発明の名称】　熱間加工用工具鋼

(57)【要約】

【課題】　靭性、延性のレベルが高く、かつT方向とＬ方向の特性の差が少ない等方性を備えた熱間加工用工具鋼を提供する。

【解決手段】　重量比でＣ：０．１０～０．７０%、Ｓｉ：０．１０～２．００%、Ｍｎ≦２．００%、Ｃｒ≦７．００%、WおよびＭｏの単独または複合で（１／２Ｗ+Ｍｏ）：０．２０～１２．００%、Ｖ≦３．００%、さらにＳ：０．００５%未満、Ｏが３０ｐｐｍ未満であり、残部が実質的にＦｅからなる組成を有し、鋼中に存在する非金属介在物の清浄度がＪＩＳ　ｄＡ６０×４００≦０．０１０%、ｄ（Ｂ+Ｃ）６０×４００≦０．０２０%の熱間加工用工具鋼である。更にＮｉ≦４．００%、Ｃｏ≦６．５０%、Ｎ≦０．２０%の一種以上を含有してもよく、好ましくは、ソーキング処理を施してなる熱間加工用工具鋼である。



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【特許請求の範囲】

【請求項1】　重量比でC：0．10～0．70%、Si：0．10～2．00%、Mn≦2．00%、Cr≦7．00%、WおよびMoの単独または複合で（1／2W+Mo）：0．20～12．00%、V≦3．00%、さらにS：0．005%未満、Oが30ppm未満であり、残部が実質的にFeからなる組成を有し、鋼中に存在する非金属介在物の清浄度がJIS　dA60×400≦0．010%、d（B+C）60×400≦0．020%であることを特徴とする熱間加工用工具鋼。

【請求項2】　重量比でC：0．10～0．70%、Si：0．10～2．00%、Mn≦2．00%、Cr≦7．00%、WおよびMoの単独または複合で（1／2W+Mo）：0．20～12．00%、V≦3．00%を含有し、更にNi≦4．00%、Co≦6．50%、N≦0．20%の一種以上、さらにS：0．005%未満、Oが30ppm未満であり、残部が実質的にFeからなる組成を有し、鋼中に存在する非金属介在物の清浄度がJIS　dA60×400≦0．010%、d（B+C）60×400≦0．020%であることを特徴とする熱間加工用工具鋼。

【請求項3】　ソーキング処理を施してなることを特徴とする請求項1ないし2に記載の熱間加工用工具鋼。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は、熱間鍛造用型、アルミダイカスト型、アルミ押出ダイスなど各種熱間金型用途に使用して、過酷な熱的、機械的応力の作用に対して、割れを生ぜず、長寿命を得ることができ、また割れが生じにくいため、硬さを上げて使用することができ、この結果として優れた耐摩耗寿命を得ることを可能にする靭性、延性のレベルが高く、かつ方向性の少ない等方性を備えた熱間加工用工具鋼鋼材に関するものである。

【0002】

【従来の技術】近年の型の形状複雑化、大型化、成形効率をあげるための型面からの冷却の過酷化、鍛造精度をあげるための型のシャープコーナー化は型の早期大割れの問題を提起し、また鍛造精度の高度化は型面の僅かなダレ、摩耗の段階で製品寸法、形状が不良となり、金型が早期に寿命に達する事例が増加してきた。この場合、早期へたり、摩耗を防止するため硬さを上げることが検討されたが早期大割れをまねく結果となっている。

【0003】従来の熱間加工用工具鋼鋼材の場合、素材の熱間加工時のファイバーに沿ってクラックが発生したり進展、破壊する場合の靭性値即ち鍛伸方向と直角方向の靭性値（T方向靭性値）が、ファイバーに対し直角方向にクラックが進展、破壊する場合の靭性値即ち鍛伸方向の靭性値（L方向靭性値）に対して低く、（例えばT方向靭性値／L方向靭性値＝0．6など）従ってファイバー方向に沿って破壊が進行しやすく、素材のT方向の靭性、延性改善が寿命向上のための最重要課題であった。

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【0004】

【発明が解決しようとする課題】従来の鋼材の場合、鍛伸方向に平行な方向の靭性値（L方向靭性値）に対し、直角方向のサンプルによる靭、延性（T方向靭性値）のレベルは上記のようにたとえば平行方向サンプルの場合の60%と明らかに低いのが通例であり、金型の耐割れ寿命は、この靭、延性の低い直角方向の靭、延性のレベルによって左右される場合が多かった。その差の原因としては、鍛伸方向に長く伸びた非金属介在物や密集した介在物の部分に剥離状破壊を生じやすく、このためファイバー方向に沿ってクラックが発生、進展しやすくなること、また鍛伸方向に伸びた縞状偏析の成分偏析濃度が高く、また縞幅が広く、ファイバー方向に強い方向性を持って配列している場合、縞状偏析に沿ってクラックが直線的に進みやすく、これが直角方向の靭性を低下させている主因であった。

【0005】

【課題を解決するための手段】本発明ではとくに鍛伸方向にのびやすい硫化物系介在物の量と大きさを極限まで減じ、また珪酸塩系、酸化物系介在物とも極少量に減らした極清浄鋼を効率よく得、さらに適切な拡散ソーキングによるミクロ偏析の低減、素延係数の適切な管理をした熱間加工による非金属介在物の形状のコントロール等を組み合わせることにより、前述した形態による破壊の傾向を減じ、鍛伸方向および直角方向の靭性レベルをともに高め、かつ直角方向の靭性値を平行方向のそれと同等ないしこれに準ずるレベル（等方性）まで高めようとするものであり、また溶解、造塊方法については真空再溶解や消耗電極式再溶解などのコストアップや能率低下をまねく特殊な方法によらず電気炉精錬－炉外精錬等の大量生産方式の中で解決を行なったものである。

【0006】即ち本発明の第1発明は、重量比でC：0．10～0．70%、Si：0．10～2．00%、Mn≦2．00%、Cr≦7．00%、WおよびMoの単独または複合で（1／2W+Mo）：0．20～12．00%、V≦3．00%、さらにS：0．005%未満、Oが30ppm未満であり、残部が実質的にFeからなる組成を有し、鋼中に存在する非金属介在物の清浄度がJIS　dA60×400≦0．010%、d（B+C）60×400≦0．020%であることを特徴とする熱間加工用工具鋼である。上記第1発明の鋼は、鍛伸方向の靭性値（L方向靭性値）とその直角方向の靭性値（T方向靭性値）の比であるT方向靭性値／L方向靭性値が0．70を越える等方性であるのがよい。また、上記第1発明の鋼の範囲は、Sが0．003%未満、非金属介在物の清浄度がJIS　dA60×400≦0．005%、T方向靭性値／L方向靭性値が0．8

5以上の等方性とするのがよい。

【0007】さらに第2発明は、重量比でC：0．10～0．70%、Si：0．10～2．00%、Mn≦2．00%、Cr≦7．00%、WおよびMoの単独または複合で（1／2W+Mo）：0．20～12．00%、V≦3．00%を含有し、更にNi≦4．00%、Co≦6．50%、N≦0．20%の一種以上、さらにS：0．005%未満、Oが30ppm未満であり、残部が実質的にFeからなる組成を有し、鋼中に存在する非金属介在物の清浄度がJIS dA60×400≦0．010%、d（B+C）60×400≦0．020%であることを特徴とする熱間加工用工具鋼である。上記第2発明の鋼は、鍛伸方向の靭性値（L方向靭性値）とその直角方向の靭性値（T方向靭性値）の比であるT方向靭性値／L方向靭性値が0．70を越える等方性であるのがよい。また、上記第2発明の範囲は、Sが0．003%未満、非金属介在物の清浄度がJIS dA60×400≦0．005%、T方向靭性値／L方向靭性値が0．85以上の等方性とするのがよい。

【0008】上記第1発明の鋼および第2発明の鋼の組成に、特殊炭化物形成元素Nb、Tiなどを単独あるいは複合で0．50%以下、金属間化合物形成による析出強化付与元素Cu、B、Al、Beなどを単独あるいは複合で3．00%以下等各種添加元素を含有さることができる。

【0009】

【発明の実施の形態】本発明の熱間加工用工具鋼として必要な各種元素の役割を次に述べる。Cは焼入れ加熱時に基地に固溶して必要な焼入れ硬さを与え、また焼もどし時特殊炭化物形成元素との間に特殊炭化物を形成、析出し、焼もどしにおける軟化抵抗と高温強度を与え、また残留炭化物を形成して高温での耐摩耗性を付与し、焼入れ加熱時の結晶粒の粗大化を防ぐ作用を有し、不可欠の重要な元素である。多すぎると炭化物量が過度に増加し、熱間工具としての必要な靭性が保持できず、また高温強度の低下もまねくので0．70%以下とし、低すぎると上記添加の効果が得られないので0．10%以上とする。

【0010】Siは製造上脱酸元素としての使用が一般に必要であり、また用途に応じ耐酸化性や500～600℃以下での焼もどし軟化抵抗を高め、またA_1変態点を上げることのために目的、用途により添加量は調整される。多すぎると靭性低下をまねき、また熱電導性を過度に低下させるので0．10～2．00%とする。Mnは基地に固溶して焼入れ性を高める効果が大きい。Mnは上記添加効果を得るために目的、用途により添加量を調整する。多すぎると焼なまし硬さを過度に高くし、被切削性を低下させ、またA_1変態点を過度に低くするので2．00%以下とする。

【0011】Crは工具として必要とされる焼入れ性を与えるための最も重要な元素である。また、耐酸化性やA_1変態点の上昇、また残留炭化物を形成して焼入れ加熱時の結晶粒の粗大化を抑制し、また耐摩耗性を高め、焼もどし時特殊炭化物を析出して昇温時の軟化抵抗を改善し、高温強度を高めるなどの効果を与えるために添加される。多すぎるとCr炭化物を過度に形成しかえって高温強度の低下をもたらすので7．00%以下とする。なお、無添加の場合もあるが、上記添加の効果を得るために一般には0．70%以上含有させるとよい。

【0012】WおよびMoは特殊炭化物を形成するもので、残留炭化物形成により焼入れ加熱時の組織粗大化を防止し、また焼もどし時微細な特殊炭化物を析出し、焼もどし軟化抵抗と高温強度を高めるための最も重要な添加元素である。またA_1変態点を高める効果を有する。Wはとくに高温強度、耐摩耗性を高める効果が大きく、一方Moは靭性の点でWの場合より有利である。多すぎると粗大な炭化物を形成し靭性の過度の低下をまねくのでWおよびMoの単独または複合（1／2W+Mo）で12．00%以下とし、低すぎると上記添加の効果が不足するので0．20%以上とする。

【0013】Vは強力な炭化物形成元素であり、残留炭化物を形成して結晶粒微細化の効果が大きく、また高温での耐摩耗性向上を与える。また焼もどし時、微細な炭化物を基地中に析出し、W、Moとの共同添加により600～650℃以上の高温域での強度を高める効果が大きく、またA_1変態点を高める効果を与える。Vは上記効果を得るために添加されるが、多すぎると粗大な炭化物を形成し、靭性の低下をまねくので3．00%以下とする。なお無添加の場合もあるが、上記添加の効果を得るために一般的には0．05%以上含有させるとよい。

【0014】Niは基地に固溶して靭性を高め、また焼入性を高めるために目的、用途により添加される。多すぎると焼なまし硬さを過度に高くし、被切削性を低下させ、またA_1変態点の過度の低下をまねくので4．00%以下とする。Coは基地に固溶して高温強度を高める作用を有する。また焼入加熱時のオーステナイト中への炭化物の固溶限を高め、焼もどし時の特殊炭化物の析出量を増加させ、また昇温時の析出炭化物の凝集抵抗を高め、この面からも高温強度特性を改善する効果を与える。また工具の使用時の昇温により表面に緻密な密着性の酸化被膜を形成させ、高温での耐摩耗性、耐焼付性を高める効果を与える。Coは上記目的のために目的、用途により添加されるが、多すぎると靭性を低下させるので6．50%以下とする。

【0015】Nは基地や炭化物中に固溶して結晶粒を微細化し、靭性を高めるために、またオーステナイトフォーマーとして低Cの場合にも焼入加熱時のフェライト残存を防ぎ靭性にすぐれた合金組成の組合せを可能とするものである。Nは上記効果を得るために目的、用途により添加されるが、Crなど熱間工具鋼の合金組成の範囲

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内で添加可能な限界量が存在するため0．20%以下とする。

【0016】Nb、Tiは強力な炭化物形成元素で、結晶粒の微細化や焼もどし時の凝集抵抗のとくに大きい微細炭化物の析出により650℃以上の高温域における軟化抵抗や高温強度を高める効果がある。上記効果を得るため目的、用途により添加される。多すぎると粗大な固溶しにくい炭化物を形成し靭性の低下をまねくので、複合あるいは単独添加で0．5%以下とする。Cu、B、Al、Beは金属間化合物を形成し析出効果をもたらし、昇温時の軟化抵抗、高温強度を改善する効果をもたらす。多すぎると靭性を低下させるので、単独あるいは複合で3．00%以下とする。

【0017】

【実施例】表1にJISのSKD61相当組成の本発明鋼、比較鋼および従来鋼の組成と非金属介在物の清浄度を示す。図1にSKD61組成の実体金型用鋼材におけるS量とJIS法による非金属介在物清浄度、鍛伸方向（L方向）とその直角方向（T方向）の平面歪み破壊靭*

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*性値KICとの関係についての実験例を示す。この場合の鍛練成形比は15（素延係数は6．5）である。S量0．014から0．006%までの減少に対し、硫化物系介在物の量、大きさは漸減し、それと共にKICは漸増するが、S量が0．005%未満を境にとくにS量が0．003%未満でT方向のKIC値は急増し、L、T方向による差が急減することが認められる。

【0018】S量の減少によりT方向TPによる靭性値が増大し、L方向のそれに近付く方向に向うことは従来から指摘されていたが、本発明者らの詳細な研究究明の結果、熱間加工用工具鋼においてS量が0．005%未満とくに0．003%付近にその効果が著しく急増する特殊点があり、これ以下のS量で急激にT方向の靭性値が増加することが新たに見出され、各種熱間金型として予想をはるかに越える優れた特性が得られたものである。

【0019】

【表1】

	C	Si	Mn	S	Cr	Mo	V	O PPm	dA60×400 (%)	d(B+C)60×400 (%)
本発明鋼 A	0.39	0.87	0.41	0.001	5.21	1.38	0.70	10	0	0.008
〃 B	0.40	0.86	0.41	0.002	5.25	1.39	0.68	11	0.004	0.012
〃 C	0.39	0.85	0.40	0.004	5.24	1.37	0.70	15	0.008	0.016
比較鋼 ①	0.40	0.89	0.43	0.006	5.25	1.36	0.69	32	0.016	0.024
〃 ②	0.38	0.89	0.44	0.008	5.30	1.35	0.68	35	0.020	0.028
〃 ③	0.39	0.90	0.43	0.010	5.31	1.38	0.71	40	0.028	0.032
従来鋼 ④	0.41	0.88	0.40	0.014	5.25	1.36	0.72	37	0.036	0.032

【0020】図2に熱処理（焼入れ、焼もどし）硬さHRC45のSKD61相当鋼材でのS：0．002%の本発明鋼およびS：0．014%の従来鋼について素延係数0～20と、L、T方向のKIC値の関係を示す。この場合鍛伸に移る前に据込みを入れており、トータル鍛練成形比は0～50となっている。本結果ではS：0．014%の従来鋼は素延係数2以上でT方向試料の靭性値の増加がみられ、素延係数4～6付近で靭性値は最大となるが、L方向の場合のKIC値の約6割（T方向靭性値／L方向靭性値の比が約0．6）の値にしかならず、素延係数10前後以上では減少の傾向を示す。

【0021】これに対し、S：0．002%の本発明鋼のもののT方向試料の靭性値は素延係数2付近で従来材の場合よりも大きく増大し、4～10付近で最大とり、その値はS：0．014%の従来鋼のT方向は勿論のことL方向よりも明らかに高く、本発明鋼のL方向のKIC値の9割以上（T方向靭性値／L方向靭性値の比が※50

※0．85以上）のKIC値を示す。かつ素延係数の増加にともなうT方向試料のKIC値の減少が従来材と比較しても生じにくく、素延係数20前後でもT方向TPのKIC値の低下は僅少である。すなわち鍛練成形比としては、1．5以上（ただし素延係数1～20）、望ましくは4以上（ただし素延係数4～10）である。

【0022】図3に熱処理（焼入れ、焼もどし）硬さHRC45でS：0．002%のSKD61組成の本発明鋼材につき素延係数5．0、鍛練成形比12．0の場合の鋼塊ソーキングおよび鍛練成形比2．3（素延係数1）の段階で鋼片ソーキング処理を施した場合の鍛造仕上後のT方向のシャルピー衝撃値の向上効果を示す。この場合のソーキング温度は1200℃以上である。ソーキング処理により凝固時のミクロ偏析を低減させることにより、T方向シャルピー衝撃値／L方向シャルピー衝撃値の比はソーキングなしの場合0．88であるのに対し、鋼塊ソーキングを施したものは0．90、鋼片ソー

キングを施したものは0．92でソーキングを施すことによりシャルピー衝撃値が向上していることが認められた。

【0023】本発明鋼を得るためには電気炉中にてあらかじめ酸化精錬→還元精錬まで進めて溶鋼中の〔O〕量を100ppm以下としたのち炉外精錬により脱硫、脱酸を効率的に進めることが有効である。この際スラグー溶鋼反応による脱硫を効率よく進ませるため電磁撹拌方式の炉外精錬により脱硫を短期間にS：0．005%未満の極低レベルまで進ませること、この際同時に下方からのAr吹込みにより溶鋼中の〔O〕量を30ppm未満まで一層低減させ、脱硫効果を一層加速させることなどがより有効である。前述の表1に示すように、本発明鋼はSが0．005%未満、Oが30ppm未満であり、望ましくはSが0．003%未満、Oが30ppm未満であり、従来鋼に比して極めて少ない。また鋼中に存在する非金属介在物の清浄度としては、JIS dA60×400≦0．010%、d（B+C）60×400≦0．020%であり、望ましくはdA60×400≦0．005%で従来鋼に比して硫化物系介在物や酸化物系介在物の量および大きさが極めて減じられている。

【0024】図4に熱処理（焼入れ、焼もどし）硬さHRC44でS：0．002%のSKD61組成の本発明鋼材およびS：0．014%のSKD61組成の従来鋼材のT方向試験片による衝撃遷移特性を示す。試験片はJIS Vノッチシャルピー試験片で20～300℃で試験を行ない、破断の吸収エネルギーの変化を調べた。素材の鍛練成形比は12．5、素延係数は5．0である。S：0．014%の従来鋼材の場合50%脆性破面遷移温度は50～100℃で、試験温度に対する吸収エネルギーの増加がみられるが、100℃を越える温度域ではその増加の度合いが小さい。これに対し、本発明鋼材の場合50%脆性破面遷移温度は同様に50～100℃であるが、試験温度の上昇に対する吸収エネルギーの増加度は明らかに大きい。このために本発明鋼材を用いた金型の場合、型予熱による衝撃吸収エネルギーを大きくすることができ、割れ低減効果が従来鋼材の場合に対し、際立って大きいことが認められる。

【0025】表2に、0.52%C-0.21%Si-0.85%Mn-1.65%Ni-1.03%Cr-0.40%Mo-0.16%V-balFeのSKT4、0.40%C-0.22%Si-0.34%Mn-4.36%Cr-4.35%W-0.35%Mo-1.98%V-4.30%Co-balFeのSKD8、0.19%C-0.25%Si-0.60%Mn-3.32%Ni-3.42%Mo-balFeの3Ni－3Mo系、0.31%C-0.33%Si-0.65%Mn-10.25%Cr-1.58%Mo-0.97%V-balFeの10Cr－Mo－V－N系の数種の熱間工具鋼について、本発明鋼材と従来鋼材のL方向およびT方向の平面歪み破壊靭性値並びにT方向靭性値とL方向靭性値の比を示す。従来鋼材の場合T方向の靭性が低く、T方向靭性値／L方向靭性値の比が0．70未満であるのに対し、本発明鋼材のT方向の靭性が際立ってすぐれており、かつT方向靭性値／L方向靭性値の比が0．70をはるかに越える0．85以上の優れた等方性を備えていることがわかる。

【0026】

【表2】

試料		平面歪み破壊靭性値 (kg/mm$^{3/2}$) L	T	T方向靭性値／L方向靭性値
SKT4 (HRC41)	従来材 0.013%S	335	224	0.67
	本発明材 0.002%S	350	322	0.92
SKD8 (HRC44)	従来材 0.012%S	135	88	0.65
	本発明材 0.001%S	140	125	0.89
3Ni-3Mo (HRC38)	従来材 0.013%S	262	173	0.66
	本発明材 0.002%S	270	245	0.90
10Cr-Mo-V-N	従来材 0.011%S	320	218	0.68
	本発明材 0.001%S	330	304	0.92

【0027】また表3に本発明鋼材および従来材を熱間プレス鍛造型に使用した場合の型寿命の比較例を示す。※

※【0028】

【表3】

9　　10

型の種類	金型材料	適用例	従来材の型寿命	本発明材の型寿命
熱間プレス鍛造型	SKD61相当	第1ケース	平均寿命6500ショット(クラックによる肌あれ)	14000ショット
	SKD61相当	第2ケース	平均寿命7000ショット(大割れ)	15000ショット

【0029】本発明鋼材の適用によりクラックの発生が遅く、進みにくくなり、かつ大割れが生じないので型寿命が従来材の2倍に向上し、安定化がはかられ実用性能が大幅に改善されることが明らかとなった。またSKD61組成の本発明鋼材を用いたアルミダイカスト金型およびSKT4組成の本発明鋼材を用いた熱間ハンマー金型においても、従来材を用いた場合の2～3倍の長寿命が得られている。

【0030】

【発明の効果】以上示したように、本発明の熱間加工用工具鋼は、靭性、延性のレベルが高く、かつT方向とL方向の特性の差が少ない等方性を備えているために、適＊用した各種熱間金型において、早期大割れを生じず、クラックの発生が遅く、進みにくいので型の長寿命並びに安定化が達成できる。

【図面の簡単な説明】

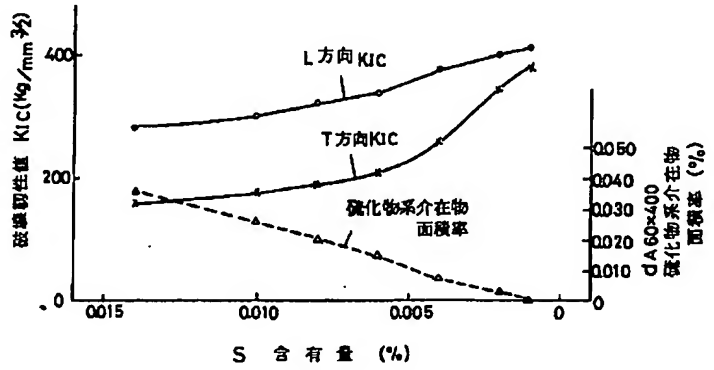
【図1】S量と硫化物介在物面積率、鍛伸方向（L方向）とその直角方向（T方向）の平面歪み破壊靭性値KICとの関係を示す図である。

【図2】素延係数とシャルピー衝撃値との関係を示す図である。

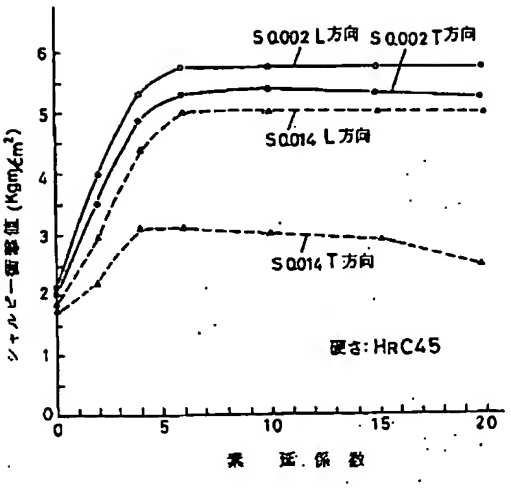
【図3】シャルピー衝撃値に及ぼすソーキングの影響を示す図である。

【図4】T方向における衝撃遷移特性を示す図である。

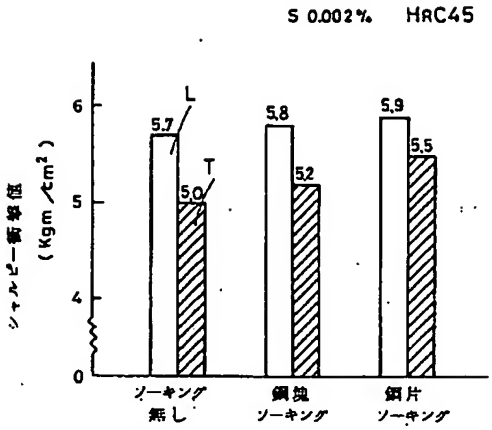
【図1】



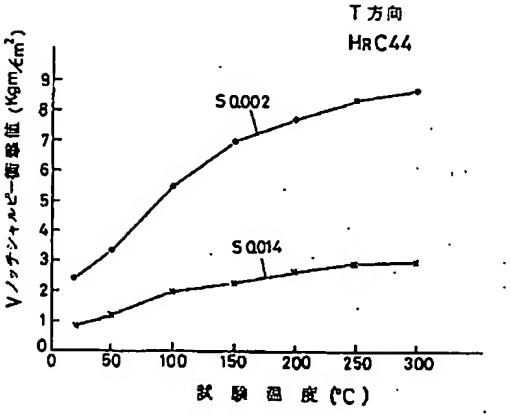
【図2】



【図3】



【図4】



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